Productivity and environmental regulations*

A long run analysis of the Swedish industry

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Abstract

The aim with this study is to evaluate the potential effects on productivity development in the Swedish manufacturing industry due to changes in environmental regulations over a long time period. The issue is closely related to the so called Porter hypothesis, i.e. whether environmental regulations (the right kind) that usually is associated with costs triggers mechanisms that enhances efficiency and productivity that finally outweighs the initial cost increase. To test our hypothesis we use historical data spanning over the period 1913-1999 for the Swedish manufacturing sector. The model used is a two stage model were the total factor productivity is calculated in the first stage, and is then used in a second stage as the dependent variable in a regression analysis where one of the independent variables is a measure of regulatory intensity. The results show that the productivity growth has varied considerably over time. The least productive period was the second world war period, whereas the period with the highest productivity growth was the period after the second world war until 1970. Development of emissions follows essentially the same path as productivity growth until 1970. After 1970, however, there is a decoupling in the sense that emissions are decreasing, both in absolute level and as emissions per unit of value added. A rather robust conclusion is that there is no evident relationship between environmental regulations and productivity growth. One explanation is that regulations and productivity actually is unrelated. Another potential explanation is that the regulatory measure used does not capture perceived regulations in a correct way.

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1. Introduction

The objective with this study is to analyze the potential effects on productivity development in the Swedish manufacturing industry due to changes in environmental regulations. More specifically the objective is to test if changes in environmental regulations have different effects on productivity in different industrial sectors and in different time periods. The issue analyzed is closely related to the so called Porter hypothesis, i.e. whether environmental regulations (the right kind) that usually is associated with costs triggers mechanisms that enhances efficiency and productivity that finally outweighs the initial cost increase (Porter & van der Linde, 1995). To test the hypothesis we develop a two stage model were the first stage consist of a, given certain assumptions, calculation of total factor productivity in each industrial sector over the period 1913-1999. The second stage is a regression analysis where changes in the calculated total factor productivity is regressed on a synthetic measure of environmental regulations. Of specific interest is whether the last period (1990-1999) differs from previous periods concerning the relation between regulations and productivity. The period 1990-1999 is specific in the sense that it can be described as a period with a new environmental regulatory regime, in which environmental taxes were introduced in a more explicit and broad scale than before. In the analysis we consider two types of emissions, related to two different environmental problems; emissions of CO_2, related to the green house gas problem; emissions of SO_2, related to the acidification problem.

The background to our study can be traced back to an idea presented by a one page article in *Scientific American* 1991 where Michael Porter claimed that a strict environmental regulation may, contrary to the conventional wisdom, lead to an improvement in competitiveness for those firms that are subject to regulation. The idea was elaborated in a paper in the *Journal of Economic Perspectives* in 1995 (van der Linde & Porter, 1995). In the same journal issue, Palmer et.al. (1995) was arguing against van der Linde & Porter. The main argument made by van der Linde & Porter was that the conventional view upon the costs of regulation was too static and do not consider the dynamic nature of the problem. They argued that regulations have dynamic effects that may fully offset what they call the static cost. The reasoning behind their argument is that regulations forces firms to improve and increase internal as well as external efficiency, this through the whole change of the production cycle. Regulations will visualize and identify inefficiencies and hence provide solutions to them. Palmer et.al. (1995) argues strongly against this. Their main argument is that firms can undertake the improvements voluntarily whenever they want. If firms do not undertake these improvements they do not do so because they don't find it profitable.

The rest of the paper is structured as follows. In the next section we elaborate further on the Porter hypthesis, discussing the arguments in favour and against. We also briefly review the literature. In section 3 we present the model underlying the empirical analysis, whereas section 4 provides a description of the data. The estimation results are presented in section 5. Section 6, finally, contains some concluding comments and an outline for future research.

2. The Porter hypothesis

As discussed above van der Linde & Porter (1995) argued that a stricter environmental policy not necessarily imply losses in competitiveness. They based this hypothesis on three arguments, basically; (1) regulations are signalling that there are room for efficiency and technological improvements; (2) regulations will cause an environmental awareness among firms which in addition to efficiency improvements triggers new ways to handle materials as well as product innovations; (3) regulations reduces some of the uncertainties that are related to investments. If firms know that they must take measures in order to comply with certain environmental regulations the number of alternatives will be reduced; (4) regulations put pressure not only on the firms that are subject to regulations, but also through the whole chain from suppliers of material and equipment to customers. To support their hypothesis van der Linde & Porter referred to a number of cases where it seems as if tighter environmental regulations have reduced overall costs for the firms, and/or improved the quality of their products. The case studies referred to was mostly firms within the chemical industry.

Palmer et.al. (1995) argued against the hypothesis, and opposed strongly to the view by van der Linde & Porter that neoclassical economists generally had a too static mindset view on the costs of environmental regulations. Instead, Palmer et.al. pointed at two fundamental differences between the Porter view and the neoclassical view. The first, according to Palmer et.al., is that van der Linde & Porter presume that that private companies systematically overlook profitable opportunities. Second, and perhaps more important, is that within the Porter view lies the presumption that the regulatory authority not only can identify these opportunities, but also can correct for those kind of failures.

The articles by van der Linde & Porter and Palmer et.al. have triggered substantial theoretical and empirical research, as well as a lively discussion of the exact meaning of the Porter hypothesis. Within the theoretical literature there has been a search for basic mechanisms that may give rise to the kind of (unclear) effects that are inherent in the Porter hypothesis. The empirical literature follows a number of different branches of the Porter hypothesis, and in the best cases they can provide partial tests of the hypothesis. The empirical literature suffers from the vagueness of the Porter hypothesis as such, but also what is meant by "environmental regulations" and how to measure them.

Broadly speaking there are three different interpretations of the Porter hypothesis, all linked to the discussion above; (1) absolute cost reductions for the regulated firms. That is, private costs for those firms that are subject to regulations are reduced. This may go through different channels (Gabel & Sinclair-Desgagné, 2001), such as improvements in internal and external organization which remove internal ineffciencies; (2) relative (to other firms) improvement in competitiveness. Although a regulation may raise cost for those who are regulated it may, due to learning effects, be more costly for those firms that are regulated later. This is what Porter denotes early-mover-advantage; (3) competitiveness improvements due to an increase in demand for products and services complementary to environmental regulations. This means that it is not the regulated firms per se that gains, but firms that delivers material and equipment to the regulated firms. Thus, according to Porter, countries that regulates may develop new products and/or equipment that can be sold to other countries when they become regulated, and hence get a relative competitive edge.

The theoretical explanations that has emerged can roughly be classified within the three categories, or interpretations, as described above; (1) models where firms are inefficient because of bounded rationality and problems with co-ordination within the company (Gabel & Sinclair-Desgagné, 1998, 2001); (2) models that focus learning, spillovers and other positive externalities related to investments and research and development (Mohr, 2002); (3) models with imperfect markets and strategic interactions (Simpson & Bradford 1996, Greaker 2006, Xepapadeas & de Zeeuw, 1999).

Xepapadeas and de Zeeuw (1999) shows that the Porter effect they derive do not completely offset the initial cost of the regulation (a tax), but that the trade off between environmental regulations and competitiveness may not, under specific assumptions, be as sharp as one would expect. Their result is based on two very central assumptions; the first is that there are two firms of which one (domestic) is subject to a regulation, and the other (foreign) is not. This assumption simply means that the firms output decision affect the market price. (the product is demanded in a third country). The second crucial assumption is that the firms capital stock consists of different vintages, where new ones are more productive and cleaner than old ones. A regulation will then provide an incentive to invest in a new machine. Investment in a new machine will then mean less pollution but they still have a cost for the investment. The higher cost, however, will due to the first assumption have a "scale effect" in the sense that production goes down with the consequence that the price of the product increases, which to some extent offset the initial cost. Simpson & Bradford (1996) succeed to show, under similar assumptions, that the regulated (domestic) firm increases its profit under the regulation scheme. But as they say, "In our model we find that this [domestic industrial advantage] may be a theoretical possibility, but that it is extremely dubious as practical advice." (Simpson and Bradford, 1996, page 296).

Mohr (2002), on the other hand, shows that there is a possibility that the costs from a regulation are more than neutralized under conditions that are similar to those discussed above. However, he adds another crucial assumption concerning learning. He assumes that there are many firms, but that they learn from each other. This learning effect means that there is a positive externality related to each firm's investment. An environmental regulation will then internalize also this externality. A possible Porter effect is thus driven by the assumption that it happens to be an additional externality that is removed as a side effect of the regulation. In other words, there is a positive externality associated with a new investment. As pointed out, environmental regulations are not unique in this respect. Any regulation which causes firms to invest earlier will do the job. Furthermore, as is shown in Feichtinger et.al. (2005), this type of effect may demand a further tightening of the regulation, which in the end lead to a loss in profits, hence rejecting the Porter hypothesis.

Another type of externality is analyzed in Greaker (2006). The idea here is that regulations give rise to a complete new industry producing abatement equipment. A regulation will boost demand for abatement equipment. It is assumed that there are high fixed costs for developing abatement equipment, and the boost in demand implies then lower average costs. The lower cost of abatement equipment may then neutralize the cost for the downstream firm (the one that is regulated). Crucial for the result, although not sufficient, is that the price of abatement capital falls as a result of the regulation. The assumptions made may be a reasonable description of reality in the beginning of a regulation process. However, in time when also the competitors become regulated they can also utilize the lower cost capital, which in turn will lower the price on the downstream market and neutralize the domestic competitive advantage.

As with the theoretical literature the empirical literature can be divided into different categories, testing various parts of the Porter hypothesis. The main categories are those testing the effects of regulations on investments and innovation, and those testing the effects on efficiency and productivity. In addition there is a substantial literature on regulatory effect on trade and firm location (see Jaffe et.al. 1995 for an overview).

The literature on innovation effects gives no clear answers to what extent regulations affects innovations. Jaffe & Palmer (1997) find no evidence that the number of successful patents would increase in the American industry as a results of tighter environmental regulations, although they find that the expenditure on abatement increases as a result of regulations. Brunnermeier och Cohen (2003), however, find a weak relationship between the number of patents and regulations in the American industry. The latter study differs from Jaffe & Palmer in the sense that Brunnermeier & Cohen focus patents related to environmental innovations. Popp (2004) finds similar results using international data. For the Japanese manufacturing industry Hamamoto (2006) finds a positive relationship between investement in R&D and regulations.

Concerning the effects on productivity and/or efficiency there is no clear or strong evidence in favour of the Porter hypothesis. On the contrary, many studies find a negative relation between environmental regulation and firm productivity or efficiency. Gollop och Roberts (1983) found that the sulphur regulations applied on American electrical utilities slowed down productivity growth by 43% in the 70-ties. Similar results was found in Smith & Sims (1985), Barbera & McConell (1990), and Gray & Shadbegian (2003). In a study of the pulp and paper industry Boyd & McClelland (1999) finds that although a potential for a more efficient use of resources and lower emissions, environmental regulations have negative effects on production. Berman & Bui (2001), however, finds that refineries located in south California (where regulations are relatively stringent) have had a significantly higher productivity than refineries in other parts of the US. Alpay et.al. (2002) find a similar result for the Mexican food industry. Hamamoto (2006) finds that environmental regulations have had a positive effect on productivity in Japanese manufacturing, via positive effects on R&D. In a study of small and medium sized firms within the Dutch horticulture industry Van der Vlist et.al.

(2007) finds that those firms that have engaged in voluntary agreements have become more efficient than firms that have not engaged in such agreements.[1]

It should be pointed out that there are problems to relate the results from these kinds of studies to the strict Porter hypothesis as described above. First of all, any positive relationship between innovation and regulation cannot be used in favour of the Porter hypothesis. In fact we would certainly expect investments in R&D to increase as a result of regulations, but that has nothing to do with the Porter hypothesis. This holds true also for the studies testing for the relation between regulations and productivity/efficiency. A positive relation works in favour of the Porter hypothesis, but is not a sufficient condition for it to hold. Secondly, the Porter hypothesis asserts that the "right kind" of regulations may neutralize costs. Most of the empirical studies referred to above do not distinguish between different kinds of regulations. In most cases environmental regulations are approximated with expenditures on abatement. Van der Vlist et.al. (2007) use participation in voluntary agreements as the regulatory variable. However, this may lead to the wrong conclusion due to a selection effect. It can't be ruled out that firms that decide to participate and engage in voluntary agreements are those firms that would invest in new technology anyway.

To summarize there are no clear evidence against or in favour of the Porter hypothesis. Concerning productivity, most studies indicate a negative productivity effect from environmental regulations.

3. The model and data

In this study we are concerned with the relation between productivity growth and environmental regulations. The approach taken is the application of a traditional exogenous growth model according to Solow (1957). In the empirical analysis where we have discrete time we calculate total factor productivity using a Törnqvist index (see for example Chambers, 1988, Grosskopf, 1993). In a second stage the Törnqvist index is used as a dependent variable in a regression where one of the explanatory variables is a proxy for environmental regulations.

The basic approach can be outlined as follows. To start with, assume that we can express production as a function of labor and capital input:

[1] Efficiency means hear the distance from the production frontier.

$$y(t) = A(t) f\left[K(t), L(t)\right], \tag{1}$$

where y is production, or value added, K and L are capital and labor input respectively, and $A(t)$ is a measure of the technological level at time t. That is, $A(t)$ shifts the production function over time, given the amount of capital and labor used. By differentiating (1) totally with respect to time, t., we get the expression:

$$\frac{\dot{y}}{y} = A \cdot \frac{f_K K}{y} \cdot \frac{\dot{K}}{K} + A \cdot \frac{f_L L}{y} \cdot \frac{\dot{L}}{L} + \frac{\dot{A}}{A}, \tag{2}$$

where a "dot" denotes a time derivativ (dy/dt), f_K is the marginal product of capital, and f_L the marginal product of labor.

If we assume perfect competition on the factor markets we know that the marginal product of each factor equals its price (normalized with the output price). This in turn implies that $Af_K K/y$ and $Af_L L/y$ are the capital and labor share respectively of the value added. Furthermore, by assuming constant returns to scale we know that the shares will sum to one, which gives us the expression:

$$\frac{\dot{y}}{y} = \alpha_K \frac{\dot{K}}{K} + (1-\alpha_K) \cdot \frac{\dot{L}}{L} + \frac{\dot{A}}{A}, \tag{3}$$

where α_K is the capital share, and (1-α_K) is the labor (wage) share of value added. The change in total factor productivity can now be expressed as:

$$\frac{\dot{A}}{A} = \frac{\dot{y}}{y} - \alpha_K \frac{\dot{K}}{K} - (1-\alpha_K) \cdot \frac{\dot{L}}{L}, \tag{4}$$

i.e., the change in total factor productivity equals the change in production minus a weighted average of the change in factor inputs..

For empirical purposes equation (4) has to be transformed to a discrete time scale. To do this we use the Törnqvist approximation which measures the logarithmic difference between t och t+1 according to.:

$$TFP_t = \ln\left[\frac{A_{t+1}}{A_t}\right] = \ln\left[\frac{y_{t+1}}{y_t}\right] - \left(\tilde{\alpha}_{K,t} \cdot \ln\left[\frac{K_{t+1}}{K_t}\right] + (1-\tilde{\alpha}_{K,t}) \cdot \ln\left[\frac{L_{t+1})}{L_t}\right]\right) \quad , \tag{5}$$

where $\tilde{\alpha}_{K,t} = 0.5 \cdot (\alpha_{K,t} + \alpha_{K,t+1})$, i.e. the mean share over t and t+1.

In the second stage of the analysis we use TFP_t as the dependent variable in a regression where our regulatory measure is included as an explanatory variable. Since we don't have any actual data on regulations we apply a synthetic measure, R, suggested by Gollop & Roberts (1983):

Data

The data used in this study is data for the Swedish manufacturing industry divided into 8 different sectors, stretching over the period 1913.-1999. The sectoral division used in the Historical National Accounts for Sweden (SHNA) dictates the organization of the data. In practice this classification is fairly consistent with the two-digit ISIC level. Some reclassifications have, however, been necessary in order to assure compatibility with the older data. The high level of aggregation naturally leads to heterogeneity in some sectors. A detailed description of the data and how it is collected and assembled can be found in Balk et.al (2006).

Value added, y, is measured in fixed prices, and labor input, L, is measured as number of employees and self-employed company owners. The capital stock is estimated by piecing together various sources of information and by using proxy indicators (see Balk et.al., 2006). The emissions considered are sulfur dioxide (SO_2) and carbon dioxide (CO_2). Emissions of sulfur dioxide were calculated on basis of estimates of total sulfur emissions from energy use. The main difficulty is the distribution of the emissions over the respective sectors. This is done by estimating historical emission factors for coal and liquid fuels and then applying the emission factors to the fuel input data. Secondly, process emissions were allocated to the sectors. The CO_2 emissions were calculated on the basis of Statistics Sweden's emission factors for various fuels. In practice the CO_2 emissions are nearly linearly dependent on the use of fossil fuels, affected only by composition changes. The data on the capital share (α_K) and labor share (1-α_K) of value added is obtained from Vikström (2002).

In summary the data used in this study spans the period 1913-1999 and cover eight Swedish manufacturing sectors. The sectors are:

1: Mining and metal industry
2: Stone, clay and glass industry

3: Wood products industry

4: Pulp. paper and printing industry

5: Food processing industry

6: Textile and clothing industry

7: Leather, hair and rubber industry

8: Chemical industry

Figure 1 gives a description of the aggregated output data that is used (value added and emissions). Here we can see that value added has been increasing more or less monotonically over the whole time period. An exception though is in the thirties and during World War II. We can also see a dip in value added at the end of the seventies, mostly due to the oil crisis.

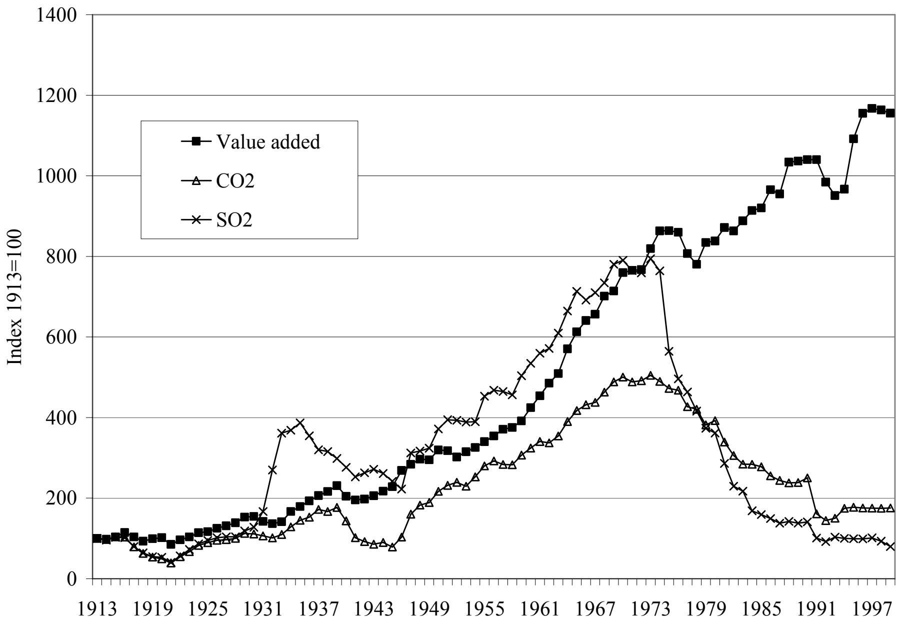

Figure 1. Value added, SO2, and CO2 emissions in Swedish manufacturing 1913-1990. Index, 1913=100.

If we look at the trends in emissions we see that they follow the value-added series closely until the mid seventies. However, in the mid seventies there is a sharp break in the trend; emissions of both sulfur and carbon dioxide start to decrease sharply. Thus, casual inspection of the simple time trends in value added and emissions would suggest that the environmental productivity, emissions per unit of output, in Swedish manufacturing have increased at a fast rate since the mid seventies.

The Box-plots in Figures 2 and 3 describe the development over time of emissions per unit of value added, including the mean and distribution across sectors. These figures show that mean emissions per unit of value added for both CO_2 and SO_2 have decreased over time. That is, the Swedish manufacturing industry has become less carbon and sulfur intensive over time. It can also be noted that the variation across sectors has decreased substantially during this period of time.

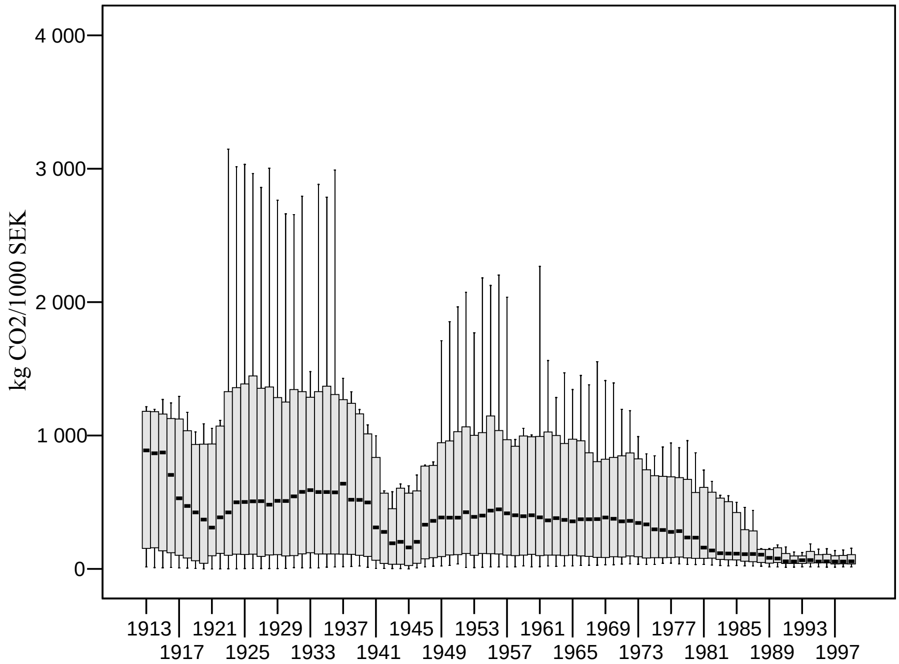

Figure 2. CO_2 emissions. 1000 kg/million SEK value added, mean and variation in each year.

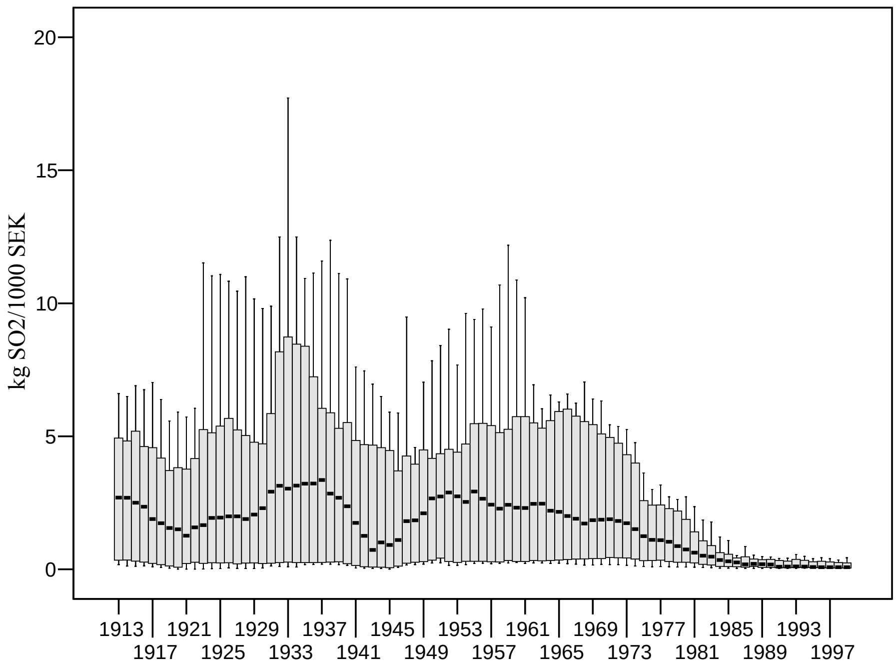

Figure 3. SO_2 emissions kg/1000 SEK value added, mean and variation in each year.

Table 1 displays the structural change within the Swedish industry since 1913 in terms of each industry's share of the value added. The metal and mining industry accounted for approximately 23% of value added in the pre-war period, whereas the chemical industry accounted for only 1%. After 1945 there has, however, been a relative strong structural change. Metal and mining, and chemistry have increased their share on the expense of almost all other industries except the pulp and paper industry. Here it can be worth noting that the industries that have expanded are those who are considered to be those who affect the environment mostly.

Table 1. Percentage share of total Swedish industrial value added for different industries.

	1913-1938	1939-1945	1946-1969	1970-1988	1989-1999
(1) Metal and mining	23	23	43	52	50
(2) Stone, clay and glass	7	6	7	5	3
(3) Wood and wood products	19	18	11	10	07
(4) Pulp and paper	11	11	11	13	16
(5) Food	25	25	14	10	10
(6) Textile	12	12	08	3	1
(7) Leather and rubber	2	2	2	1	1
(8) Chemical	1	1	3	6	11

Empirical model

Given the data we calculate, in the first stage, the productivity change in each sector according to:

$$TFP_{i,t} = \ln\left[\frac{A_{i,t+1}}{A_{i,t}}\right] = \ln\left[\frac{y_{i,t+1}}{y_{i,t}}\right] - \left(\tilde{\alpha}_{i,K,t}\cdot\ln\left[\frac{K_{i,t+1}}{K_{i,t}}\right] + (1-\tilde{\alpha}_{K,t})\cdot\ln\left[\frac{L_{i,t+1})}{L_{i,t}}\right]\right),\ i = 1,\ldots,8,\ (6)$$

where $\tilde{\alpha}_{i,K,t} = 0.5\cdot(\alpha_{i,K,t} + \alpha_{i,K,t+1})$, i.e. the mean share over t and t+1.

In the second stage $TFP_{i,t}$ in equation (6) is regressed on a regulator measure. However, no direct regulatory measure exists. To overcome this problem a regulatory index has been created using actual emissions. The index, which is similar to the index suggested in Gollop and Roberts (1983), consist essentially of two parts; a part that measures the tightness of regulations, which is measured as the difference between desired emission (unregulated) and actual emissions, divided by desired emissions. The second part measures the degree of compliance on a scale between 0 and 1. In this study we only use the first part of that index, the tightness part.

Specifically the index applied can be written as:

$$R_{i,t} = \frac{z^*_{i,t} - z_{i,t}}{z^*_{i,t}}, \quad i = 1, \ldots, 8, \tag{7}$$

where z^* is the desired, or unregulated, emission level, and z the actual emissions. It is clear that $0 \leq R \leq 1$. The desired emission level in any time period, z^*, is defined as the highest emission level during a five year period. That is,

$$z^*_{i,t} = \max z_{i,\tau}, \tau \in [t, t+4] \tag{8}$$

A high value of R implies then a relative strict regulation, compared to a low value of R which implies a lax regulation since actual emissions then are close to desired emissions. If $R = 0$, then actual emissions equals desired emissions, i.e. no regulatory pressure on the margin.

The regulatory index is computed for both SO_2 and CO_2 emissions and is based not on absolute emissions but on emissions per unit value added. Emissions per unit value added depends probably less on short run factors such as the business cycle, than absolute emissions.

There are of course several problems connected with a regulatory measure of this type, especially when we consider such a long time period. Emissions of SO_2 and CO_2 have not been viewed as any major problem until the last 30-40 years. Thus a high value of R may not correspond to tight regulations when we go back in time. An attempt to control for this is made by using an interaction term in which time and R interacts. That is, the effect of R is allowed to vary between time periods. Furthermore we allow TFP to be time specific, in the sense that we allow TFP to vary over time independent of regulations. Finally we include a variable measuring nuclear power capacity. The latter may be important since it was a rather massive introduction of nuclear power in Sweden in the 70'ies that may have affected productivity in the Swedish industry.

The specification that is used in the second stage can then be written as:

$$TFP_{i,t} = C_i + \sum_{k=1}^{4} \beta_{i,k} D_{i,k,t} + \alpha_i R_{i,t} + \sum_{k=1}^{4} \alpha_{i,k} D_{i,k,t} R_{i,t} + \gamma_i NUC_t + \varepsilon_{i,t}, \qquad (9)$$

where the index i = 1,…, 8 refers to the sectors:

1: Mining and metal industry
2: Stone, clay and glass industry
3: Wood products industry
4: Pulp. paper and printing industry
5: Food processing industry
6: Textile and clothing industry
7: Leather, hair and rubber industry
8: Chemical industry

t = 1913-1999

$D_{i,1,t}$ = 1 if: $1939 \leq t \leq 1945$; 0 otherwise.

$D_{i,2,t}$ = 1 if: $1946 \leq t \leq 1969$; 0 otherwise.

$D_{i,3,t}$ = 1 if: $1970 \leq t \leq 1989$; 0 otherwise.

$D_{i,4,t}$ = 1 if: $1990 \leq t \leq 1999$; 0 otherwise.

NUC_t = total installed effect in nuclear electricity production in period t, and R is defined by equations (7) and (8).

The results from the calculations of TFP in equation (8), and the second stage results obtained from equation (9) are presented in the next section.

4. Results

The results from the calculation of total factor productivity according to equation (6) are displayed in table 2, together with changes in emissions. The results are presented as a yearly average for the specific time period. A positive value of TFP implies that value added has increased more than the weighted sum of labor and capital, i.e. productivity has increased. Environmental productivity is displayed as percentage changes of emissions, in absolute levels and as changes in emissions per unit of value added.

The period 1913-1999 has been divided into 5 sub-periods; the pre-war period, 1913-1938; the war period, 1939-1945; the after-war period, 1946-1969; the nuclear period, 1970-1988; and the green tax period, 1989-1999.

Table 2. Productivity growth and environmental effectivenss in the Swedish industry 1913-1999. Annual percentage change.

	Metal and mining	Stone, clay and glass	wood	Pulp and paper	Food	Textile	Leather and rubber	chemical	Industry[a]
				1913 – 1938					
TFP	1.60	2.01	0.31	0.05	1.86	1.69	0.39	1.43	1.26
CO2	3.76	4.57	17.88	5.83	17.08	3.46	3.71	3.32	5.15
CO2FV	-1.62	0.05	15.86	0.77	14.13	0.37	1.66	-2.13	3.63
SO2	14.00	4.59	17.66	6.41	17.08	3.49	3.69	3.39	10.28
SO2FV	10.7	0.07	15.58	1.06	14.13	0.39	1.65	-2.06	5.19
				1939 – 1945					
TFP	-7.01	-2.51	-0.34	-1.16	-1.59	-1.26	1.47	-3.2	-2.55
CO2	-7.79	-3.7	-30.42	-27.09	-11.82	-20.57	6.62	-5.32	-8.36
CO2FV	-6.20	-7.66	-31.72	-28.00	-25.8	-22.87	-3.47	-10.32	-17.00
SO2	2.11	-3.75	-30.38	-13.29	17.08	-20.75	6.98	-5.23	0.17
SO2FV	10.7	-7.72	-31.72	-15.77	-13.99	-23.05	-3.24	-10.3	-11.88
				1946 – 1969					
TFP	4.47	3.30	3.55	2.05	1.25	2.99	3.48	3.34	3.39
CO2	8.89	5.79	94.99	25.70	6.45	15.98	7.54	8.99	9.60
CO2FV	0.87	1.47	74.98	16.93	4.55	13.63	2.98	1.15	14.57
SO2	2.39	6.74	110.48	16.26	7.70	18.41	8.89	10.15	8.43
SO2FV	-4.68	2.34	87.24	10.08	5.81	16.01	4.24	2.21	15.41
				1970 – 1988					
TFP	1.63	1.04	0.22	2.14	0.29	1.29	-0.43	3.83	1.49
CO2	-1.51	-3.8	-2.43	-6.03	-2.03	-7.18	-9.77	-4.39	-3.28
CO2FV	-3.56	-3.00	-2.93	-9.11	-2.08	-3.14	-7.5	-9.57	-5.11
SO2	-7.06	-9.07	-6.41	-6.35	-6.42	-11.05	-12.27	-9.15	-7.54
SO2FV	-9.01	-8.29	-7.08	-9.88	-6.62	-7.16	-10.1	-14.29	-9.05
				1989 – 1999					
TFP	0.69	4.94	-0.71	-0.28	2.20	3.58	3.36	-3.10	0.32
CO2	-5.06	-1.60	-0.65	3.01	0.02	-3.15	-6.61	6.52	-0.86
CO2FV	-6.00	1.92	-0.24	2.43	-1.64	0.39	-6.42	2.05	-0.94
SO2	-6.68	-5.76	-0.2	-2.31	-1.78	-1.30	-9.81	-0.08	-3.69
SO2FV	-7.46	-2.27	0.27	-2.61	-3.49	2.12	-9.57	-4.36	-3.42

[a] Vägt genomsnitt för samtliga branscher, där vikterna är respektive bransch andel av det totala förädlingsvärdet

TFP = percentage change in total factor productivity, yearly average.
CO2 = percentage change in CO_2 emissions, yearly average.
CO2FV = percentage change in CO_2 emissions per unit value added, yearly average.
SO2 = percentage change in SO_2 emissions, yearly average.
SO2FV = percentage change in sO_2 emissions per unit value added, yearly average.

From table 2 it can be seen that there are differences both in TFP and environmental productivity between the different sub-periods. Furthermore there is a variation between sectors within each subperiod. As expected, the war period is characterized with low productivity growth. In fact, productivity decreases during this time period. The war period can be viewed as an involuntary adjustment of the Swedish energy system where imported fossil fuels where replaced by mainly domestic renewable fuels such as forest fuels. This change of the energy system becomes clear when looking at the emission changes, which shows a considerable decrease of both CO_2 and SO_2. Worth noting here is that the absolute level of emissions in general decreased faster than the emissions per unit of value added, which indicates that the radical change in energy supply did not affect energy efficiency positively.

The period 1945-1969 is dramatically different concerning productivity. The yearly average productivity increase between 1946 and 1969 is 3.4%. This period is thus the most productive period in Swedish manufacturing. On the sectoral level it is only the pulp and paper industry and food industry that have a productivity growth lower than 2%. At the same it can be seen that CO_2 emissions increases by almost 10% per year, whereas SO_2 increases by 8.5% (in absolute levels). Again, emissions per unit of value added increases even faster, implying more fossil fuel intensive production also during this period.

The period 1970-1988 deviates from the preceeding period both when it comes to productivity and emissions, especially the latter. As can be seen from table 2, emissions are decreasing both in absolute terms and in terms of emissions per unit of value added. This pattern is similar in all industrial sectors, implying a "decoupling" between growth and emissions. The change in emissions was possible due to the massive expansion of nuclear power during this period, but also due to the increase in the use of biofuels.

Finally the period 1989-1999, the green tax period, is characterized by a rather, between sectors, diverse development. Some sectors have a relative strong productivity development, whereas others have a weak, or even negative, productivity development. Those with the strongest development are stone, clay and glass industry; food industry; textile industry; and leather and rubber industry. This last period is specific in the sense that the SO_2 tax and the CO_2 tax was introduced during this period in Sweden. The CO_2 tax, which was introduced January 1 1991, was set to SEK 250 per ton CO_2 (USD 36 per ton), which to some extent was compensated by a 50% decrease of the energy tax. In total the introduction of the CO_2 tax implied a higher tax on fossil fuels. The SO_2 tax, which was introduced the same year, was set to SEK 30 per kg sulphur in fuels (USD 4 per kg). After the tax reform in 1991 there has been several adjustments of the energy tax system and a continuous increase of the CO_2 tax rate, but the rate that hit the most energy intensive part of the industry have not increased at the same pace as the general rate. In summary one can say that there was a rather sharp increase in the tax of fossil fuels during the first part of the 90'ies, but that there has been a moderation during the second part. Furthermore, the effective tax rate differs between sectors.

Until 1970 there is a negative relationship between productivity change and change in environmental effectiveness for all sectors in the industry, i.e. higher productivity is accompanied with higher emissions (both in absolute level and per unit value added). After 1970 this pattern is reversed, i.e. higher productivity is accompanied with lower emissions.

The main results from the second stage of the analysis are presented in table 3.[2] The regulatory index used in the regression model presented in table 3 is based on the emissions of CO_2 per unit value added. Several other measures (based on sulphur and absolute levels) have bee tried, but the results remains essentially unchanged (see appendix 1).

Row 2 to 5 corresponds to the period specific effects, whereas row 6 to 10 corresponds to the regulatory effects, which are of specific interest.

In general there are very few significant relationships between the regulatory index and productivity growth. A significant positive relationship is found for the period after the second world war for the metal and mining sector. This, however, do probably reveal the problem with the specific regulatory measure used than a real causal relationship since environmental concern was a minor issue during this period. More likely the result mirrors the sharp general increase in productivity during this period. A positive relationship can also be found in the stone, clay and glass industry, as well as in the food industry. However, neither of these industries shows any significant differences between the time periods. The latter contradicts the interpretation that the relationship is causal. The rubber industry on the other hand show a significant positive relationship for the last period, the tax period, which may provide support for the Porter hypothesis for this particular industry.[3]

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[2] Detailed estimation results for each sector are presented in appendix 1. Table 3 focus the time specific and regulatory effects only.

[3] As pointed out earlier, a positive effect is not sufficient for a strict Porter effect.

Table 5.3. Regression results, change in total factor productivity. Dependent variable is TFP. t-values within parenthesis.

	Metal and mining	Stone, clay and glass	wood	Pulp and paper	Food	Textile	Leather and rubber	chemical
C	2.32	-0.70	-0.34	0.05	-0.80	0.87	-1.57	-1.81
	(1.41)	(-0.39)	(-0.12)	(0.02)	(-0.69)	(0.48)	(-0.81)	(-0.67)
39-45	-7.72*	-7.18	-7.75	-3.16	-4.93	-3.46	4.24	-4.24
	(-2.07)	(-1.69)	(-1.48)	(-0.52)	(-1.84)	(-0.76)	(1.02)	(-0.76)
46-69	-0.71	2.23	-0.85	-0.94	0.09	2.78	4.78	3.80
	(-0.30)	(0.90)	(-0.19)	(-0.23)	(0.05)	(1.06)	(1.67)	(0.94)
70-88	-1.16	1.29	0.82	2.21	0.57	0.17	0.76	6.57
	(-0.49)	(0.50)	(0.23)	(0.53)	(0.32)	(0.06)	(0.28)	(1.74)
89-99	-2.01	6.98	-0.38	1.37	1.11	2.68	0.10	-5.64
	(-0.64)	(1.59)	(-0.09)	(0.21)	(0.39)	(0.83)	(0.02)	(-1.11)
R	-11.19	30.02	0.72	4.53	20.56*	10.24	19.36	53.57
	(-0.88)	(1.98)	(0.13)	(0.25)	(4.55)	(0.71)	(1.61)	(1.61)
R39-45	-9.33	8.49	15.97	1.39	1.26	-6.69	-25.37	-27.36
	(-0.30)	(0.33)	(1.78)	(0.06)	(0.13)	(-0.40)	(-1.51)	(-0.63)
R46-69	64.05*	2.25	15.95	26.52	2.06	-16.57	-17.01	-40.26
	(2.90)	(0.09)	(1.31)	(1.07)	(0.20)	(-0.94)	(-0.98)	(-1.01)
R70-88	31.32	-17.84	-5.33	-8.10	-10.66	-4.77	-1.00	-81.97
	(0.80)	(-0.61)	(-0.22)	(-0.19)	(-0.68)	(-0.14)	(-0.02)	(-1.53)
R89-99	22.52	-38.89	-0.46	-15.41	-0.44	-9.70	207.42*	-13.88
	(0.45)	(-1.46)	(-0.01)	(-0.47)	(-0.01)	(-0.28)	(2.92)	(-0.32)
R2	0.17	0.09	0.03	0.04	0.26	0.04	0.09	0.04
DW	1.61	1.62	1.98	2.53	1.94	2.47	2.05	1.86
NOBS	86	86	86	86	86	86	86	86

* = Significant different from zero at the 10% level

The results in table 4 show the results from an alternative approach where the last periods are analyzed separately. A panel approach is used, employing sector specific fixed effects, as well as an interaction term between the sector dummy and the regulatory index, *R*. In addition, two different regulation measures are used. In "model 1" we use the same measure as above, whereas in "model 2" we use the annual change in emissions per unit of value added as a regulatory measure. The interpretation of this latter measure is that a decrease implies a stricter regulation. Thus we would expect an opposite sign of the coefficient, compared to the coefficient corresponding to the first measure ("model 1").

The results in table 4 do not reveal any specific strong patterns between total factor productivity and the regulatory measures employed. The only significant result can be found in "model 2" for the period 1970-1999, where there is a common negative relationship between productivity growth and change in emissions, implying that a decrease in emission (per unit of value added), is coupled with an increase in productivity growth. However, there are no significant differences between the industrial sectors, nor can we find this effect for the period 1989-1999, a period we really would expect a Porter effect. An alternative explanation to the significant negative sign is the increase of electricity from nuclear power, which is free from emissions.

Table 4. Regression results, change in total factor productivity. Dependent variable is TFP for the periods 1970 and 1989-199. t-values within parenthesis.

	Model 1 70-99	**Model 2 70-99**	**Model 1 89-99**	**Model 2 89-99**
C	0.90	0.57	0.12	- 0.27
	(0.66)	(0.54)	(0.04)	(- 0.13)
Stone, clay and glass	0.59	1.46	5.63	5.03
	(0.30)	(0.99)	(1.23)	(1.74)
Wood	- 0.80	-1.23	-0.46	-0.88
	-(0.40)	(-0.83)	(-0.12)	(-0.30)
Pulp and paper	1.33	-0.51	1.06	-0.17
	(0.68)	(-0.34)	(0.24)	(-0.06)
Food	-.99	0.15	0.38	1.96
	(-0.49)	(0.10)	(0.08)	(0.66)
Textile	1.07	0.81	3.43	3.66
	(0.56)	(0.55)	(1.00)	(1.27)
Leather and rubber	-1.72	-0.98	-1.97	-0.73
	(-0.91)	(-0.63)	(-0.57)	(-0.23)
Chemical	0.50	-0.66	-7.50	-2.40
	(0.26)	(-0.44)	(-1.96)	(-0.83)
R	15.26	-0.16	13.33	-0.17
	(0.56)	(-2.07)	(0.28)	(-1.44)
R_ Stone, clay and glass	-4.06	-5.36	-22.86	-11.32
	(-0.13)	(-0.37)	(-0.44)	(-0.55)
R_Wood	-18.48	-10.94	-13.05	-12.19
	(-0.59)	(-0.87)	(-0.23)	(-0.57)
R_Pulp and paper	-27.34	-7.27	-24.02	15.45
	(-0.93)	(-0.69)	(-0.47)	(0.79)
R_Food	-0.00	6.76	6.14	6.16
	(-0.00)	(0.60)	(0.10)	(0.33)
R_Textile	-13.35	-16.52	-13.13	-16.35
	(-0.41)	(-1.27)	(-0.25)	(-0.82)
R_Leather and rubber	64.56	-0.54	218.49	-30.52
	(1.55)	(-0.05)	(2.80)	(-1.55)
R_Chemical	-13.37	-11.42	26.73	10.30
	(-0.44)	(-1.12)	(0.52)	(0.65)
R2	0.02	0.20	0.14	0.18
DW	2.20	1.66	1.40	1.29
NOBS	240	240	88	88

Modell 1: $R = (z^*-z)/z^*$
Modell 2: $R = (CO_2(t)-CO_2(t-1))/CO_2(t-1)$.

5. Summary and concluding remarks

The aim with this study is to evaluate the potential effects on productivity development in the Swedish manufacturing industry due to changes in environmental regulations over a long time period. The issue is closely related to the so called Porter hypothesis, i.e. whether environmental regulations (the right kind) that usually is associated with costs triggers mechanisms that enhances efficiency and productivity that finally outweighs the initial cost increase. To test our hypothesis we use historical data spanning over the period 1913-1999 for the Swedish manufacturing sector. The model used is a two stage model were the total factor productivity is calculated in the first stage, and is then used in a second stage as the dependent variable in a regression analysis where one of the independent variables is a measure of regulatory intensity.

The results show that the productivity growth has varied considerably over time. The least productive period was the second world war period, whereas the period with the highest productivity growth was the period after the second world war until 1970. Development of emissions follows essentially the same path as productivity growth until 1970. After 1970, however, there is a decoupling in the sense that emissions are decreasing, both in absolute level and as emissions per unit of value added.

Concerning the relationship between regulations and productivity growth, a rather robust conclusion is that there is no clear relationship, given the regulatory measure used. One explanation is that the effect does not exist, or that it is too small to be measured compared to other factors affecting productivity growth. Another potential explanation is that the measure used do not capture actual regulations in a correct way. A tentative conclusion, though, is that the part of the Porter hypothesis that asserts that the right kind of regulations enhances productivity can be rejected.

A crucial factor in the analysis is of course the regulatory measure used. It can’t be ruled out that the results obtained here are flawed due to a bad measure of regulatory intensity. Thus, a subject for future research is to find more accurate measures of regulations. If the issue is the Porter hypothesis, a potential avenue to proceed on in this respect is to more clearly identify different regulatory regimes. This may be particularly fruitful using a cross country panel data set.

References

Alpay, E., Buccola, S. and Kerkvliet, J. (2002). Productivity Growth and Environmental Regulation in Mexican and U.S. Food Manufacturing. *American Journal of Agricultural Economics*, 84(4), 887-901.

Balk, B. M., Brännlund, R., Färe, R., Lindmark, M. and Grosskopf, S. (2006). Environmental Performance in Swedish Manufacturing, 1913-1990. In Aronsson, T., Axelsson, R. and Brännlund, R.(eds.) *Contributions in Environmental Economics: Essays in honor of Karl-Gustaf Löfgren*. Edward Elgar Publishing Company.

Barbera, A.J. and McConnell, V. D. (1990). The Impact of Environmental Regulations on Industry Productivity: Direct and Indirect Effects. *Journal of Environmental Economics and Management*, 18, 50-65.

Berman, E. and Bui, L.T.M. (2001). Environmental regulation and productivity: evidence from oil refineries. *The Review of Economics and Statistics*, 83(3): 498-510.

Boyd, G A och J D McClelland (1999). The Impact of Environmental Constraints on Productivity Improvement in Integrated Paper Plants. *Journal of Environmental Economics and Management*, 38, 121-42.

Brunnermeier, S.B. and Cohen, M.A. (2003). Determinants of environmental innovation in US manufacturing industries. *Journal of Environmental Economics and Management*, 45, 278-293.

Chambers, R. G. (1988) *Applied Production Analysis*. A Dual Approach. Cambridge University Press.

Dufour, C., Lanoie, P. and Patry, M. (1998). Regulation and Productivity, *Journal of Productivity Analysis*, 9, 233-247.

Feichtinger, G., Hartl, R.F., Kort, P.M., and Veliov, V.M. (2005). Environmental policy, the porter hypothesis and the composition of capital: Effects of learning and technological progress. *Journal of Environmental Economics and Management*, 50, 434-446.

Gabel, L. H. and Sinclair-Desgagné, B. (1998). The firm its routines, and the environment. In Folmer, H. and Tietenberg, T. (eds.), *The International Yearbook of Environmental and Resource Economics 1998/1999*. Edward Elgar publishing company.

Gabel, L. H. and Sinclair-Desgagné, B. (2001). The firm its procedures and win-win environmental regulations. In Folmer, H., Gabel, L. H., Gerkin, S., and Rose, A. (eds.), *Frontiers of Environmental Economics*. Edward Elgar publishing company.

Gollop, F.M. and Roberts, M.J. (1983). Environmental Regulations and Productivity Growth: The Case of Fossil-fuelled Electric Power Generation. *Journal of Political Economy*, 91, 654-674.

Gray, W.B. and Shadbegian, R.J. (2003). Plant vintage, technology, and environmental regulation. *Journal of Environmental Economics and Management*, 46, 384-402.

Greaker, M. (2006). Spillovers in the development of new pollution abatement technology: A new look at the Porter-hypothesis Strategic environmental policy. *Journal of Environmental Economics and Management*, 52, 411-420.

Grosskopf, S. (1993). Efficiency and Productivity. In Fried, H. O., Lovell, C. A. K., and Schmidt, S. S. (eds.), *The Measurement of Productive Efficiency, Techniques and Applications*. Oxford University Press, Oxford.

Hamamoto, M. (2006). Environmental Regulation and the Productivity of Japanes Manufacturing Industries. Resource and Energy Economics, 28, 299-312.

Jaffe, A.B. and Palmer, K. (1997). Environmental Regulation and Innovation: A Panel Data Study. *The Review of Economics and Statistics*, 79, 610-619.

Jaffe A.B., Peterson, S.R., Portney, P.R and Stavins, R.N. (1995). Environmental Regulation and the Competitiveness of U.S. Manufacturing: What Does the Evidence Tell Us? *Journal of Economic Literature*, XXXIII, 132-163.

Mohr R. D. (2002). Technical Change, External Economies, and the Porter Hypothesis. *Journal of Environmental Economics and Management*, 43, 158-168.

Palmer, K., Oates, W.E. and Portney, P.R. (1995). Thightening Environmental Standards: The Benefit-Cost or the No-Cost Paradigm? *Journal of Economic Perspectives*, 9, 119-132.

Popp, D., (2004) International innovation and diffusion of air pollution control technologies: the effects of NOx and SO2 regulation in the U.S., Japan and Germany. NBER Working paper 10643.

Porter, M. E. (1991). America´s Green Strategy. *Scientific American*,. April, p 168.

Simpson D. and Bradford, R. L. (1996). Taxing Variable Cost: Environmental Regulation as Industrial Policy. *Journal of Environmental Economics and Managemen*, 30, 282-300.

Solow. R. M. (1957). Technical Change and the Aggregate Production Function. *Review of Economics and Statistics*, 39.

Smith J.B. and Sims, W.A. (1985). The Impact of Pollution Charges on Productivity Growth in Canadian Brewing. *The Rand Journal of Economics*, 16, 410-423.

Xepapadeas, A. and de Zeeuw, A. (1999). Environmental Policy and Competitiveness: The Porter Hypothesis and the Composition of Capital. *Journal of Environmental Economics and Management*, 37, 165-182.

Van der Vlist, A.J., Withagen, C. and Folmer, H. (2007) Technical efficiency under alternative environmental regulatory regimes: The case of Dutch horticulture. *Ecological Economics*, in press.

Vikström, P. (2002). The big picture: a historical national accounts approach to growth, structural change and income distribution in Sweden 1870-1990. Umeå studies in economic history, Umeå University.

Appendix 1.

Table A1. Regression results. Dependent variable is change in total factor procutivity, t-values within parenthesis.

Metal and mining					
	Model 1	Model 2	Model 3 CO2	Model 4 CO2/FV	Model5 CO2/FV
C	1.48	1.48	0.74	2.32	0.74
	(1.07)	(1.06)	(0.35)	(1.41)	(0.35)
39-45	-8.49	-8.49	-6.53	-7.72	-6.53
	(-2.87)	(-2.85)	(-1.68)	(-2.07)	(-1.66)
46-69	2.99	2.99	-1.61	-0.71	-1.61
	(1.51)	(1.51)	(-0.46)	(-0.30)	(-0.45)
70-88	0.14	-0.07	-1.12	-1.16	-1.48
	(0.07)	(-0.02)	(-0.36)	(-0.49)	(-0.39)
89-99	-0.76	-1.19	2.33	-2.01	1.66
	(-0.30)	(-0.24)	(0.63)	(-0.64)	(0.30)
R			3.53	-11.19	3.53
			(0.47)	(-0.88)	(0.47)
R39-45			-10.58	-9.33	-10.58
			(-0.75)	(-0.30)	(-0.74)
R46-69			23.18	64.05	23.18
			(1.62)	(2.90)	(1.61)
R70-88			32.98	31.32	33.26
			(1.01)	(0.80)	(1.01)
R89-99			-74.48	22.52	-74.50
			(-1.14)	(0.45)	(-1.14)
Nuclear		0.04			0.06
		(0.10)			(0.16)
R2	0.12	0.11	0.15	0.17	.0.14
DW	1,78	1.80	1.77	1.61	1.78
NOBS	86	86	86	86	86

Table A1 (continued)

	Stone, clay and glass industry				
	Model 1	Model 2	Model 3 CO2	Model 4 CO2/FV	Model5 CO2/FV
C	1.40	1.40	-2.17	-0.70	-0.69
	0.96	(0.95)	(-1.09)	(-0.39)	(-0.39)
39-45	-3.92	-3.92	-7.83	-7.18	-7.18
	-1.26	(-1.24)	(-1.51)	(-1.69)	(-1.67)
46-69	1.90	1.90	2.51	2.23	2.23
	0.91	(0.91)	(0.76)	(0.90)	(0.89)
70-88	-0.35	-1.14	2.73	1.29	1.11
	-0.16	(-0.36)	(1.01)	(0.50)	(0.33)
89-99	3.54	2.03	10.11	6.98	6.54
	1.29	(0.39)	(2.79)	(1.59)	(0.95)
R			20.20	30.02	30.02
			(2.45)	(1.98)	(1.97)
R39-45			5.57	8.49	8.49
			(0.35)	(0.33)	(0.33)
R46-69			1.36	2.25	2.25
			(0.07)	(0.09)	(0.09)
R70-88			-4.43	-17.84	-19.36
			(-0.14)	(-0.61)	(-0.56)
R89-99			-72.34	-38.89	-38.88
			(-1.96)	(-1.46)	(-1.45)
Nuclear		0.14			0.04
		(0.34)			(0.08)
R2	0.02	0.07	0.11	0.09	0.07
DW	1.51	1.52	1.76	1.62	1.63
NOBS	86	86	86	86	86
R2	0.004	0,004	0.07	0.03	0.02
DW	1.83	1.84	2.08	1.98	1.97
NOBS	86	86	86	86	86

Table A1 (continued)

Wood industry					
	Model 1	Model 2	Model 3	Model 4	Model5
			CO2	CO2/FV	CO2/FV
C	-0.5	-0.05	-0.22	-0.34	-0.34
	(-0.30)	(-0.03)	(-0.08)	(-0.12)	-0.12
39-45	-0.29	-0.29	-7.51	-7.75	-7.75
	(-0.08)	(-0.08)	(-1.43)	(-1.48)	-1.47
46-69	3.59	3.59	-8.07	-0.85	-0.85
	(1.55)	(1.54)	(-1.42)	(-0.19)	-0.19
70-88	0.27	0.10	0.49	0.82	1.12
	(0.11)	(0.03)	(0.14)	(0.23)	0.20
89-99	-0.66	-0.98	1.79	-0.38	0.04
	(-0.22)	(-0.17)	(0.40)	(-0.09)	0.01
R			0.38	0.72	0.73
			(0.07)	(0.13)	0.13
R39-45			14.18	15.97	15.97
			(1.67)	(1.78)	1.76
R46-69			32.11	15.95	15.95
			(2.29)	(1.31)	1.30
R70-88			-1.65	-5.33	-6.61
			(-0.06)	(-0.22)	-0.22
R89-99			-48.74	-0.46	-0.43
			(-0.94)	(-0.01)	-0.01
Nuclear		0.03			-0.04
		(0.06)			-0.07
R2	0.004	0,004	0.07	0.03	0.02
DW	1.83	1.84	2.08	1.98	1.97
NOBS	86	86	86	86	86

Table A1 (continued)

	Pulp and paper industry				
	Model 1	Model 2	Model 3 CO2	Model 4 CO2/FV	Model5 CO2/FV
C	0.66	0.66	1.14	0.05	0.05
	(0.32)	(0.32)	(0.33)	0.02	(0.02)
39-45	-1.82	-1.82	-4.64	-3.16	-3.16
	(-0.41)	(-0.41)	(-0.72)	-0.52	(-0.52)
46-69	1.38	1.38	-4.48	-0.94	-0.93
	(0.47)	(0.47)	(-0.83)	-0.23	(-0.22)
70-88	1.47	0.29	2.45	2.21	0.69
	(0.48)	(0.06)	(0.55)	0.53	(0.13)
89-99	-0.94	-3.21	-0.38	1.37	-2.44
	(-0.24)	(-0.44)	(-0.05)	0.21	(-0.24)
R			-2.10	4.53	4.53
			(-0.17)	0.25	(0.25)
R39-45			8.00	1.39	1.39
			(0.53)	0.06	(0.06)
R46-69			30.02	26.52	26.52
			(1.36)	1.07	(1.07)
R70-88			-75.65	-8.10	-21.47
			(-0.93)	-0.19	(-0.42)
R89-99			-3.66	-15.41	-15.46
			(-0.13)	-0.47	(-0.46)
Nuclear		0.22			0.36
		(0.36)			(0.50)
R2	0.01	0.01	0.03	0.04	0.06
DW	2.43	2.44	2.53	2.53	2.53
NOBS	86	86	86	86	86

Table A1 (continued)

	Food industry				
	Model 1	Model 2	Model 3 CO2	Model 4 CO2/FV	Model5 CO2/FV
C	2.02	2.02	-1.19	-0.80	-0.81
	(1.75)	(1.74)	(-0.83)	(-0.69)	(-0.69)
39-45	-3.61	-3.61	-4.72	-4.93	-4.93
	(-1.46)	(-1.45)	(-1.56)	(-1.84)	(-1.83)
46-69	-0.78	-0.78	-1.09	0.09	0.09
	(-0.47)	(-0.47)	(-0.49)	(0.05)	(0.05)
70-88	-1.73	-2.24	1.10	0.57	0.40
	(-1.00)	(-0.89)	(0.55)	(0.32)	(0.17)
89-99	0.17	-0.82	2.59	1.11	0.71
	(0.07)	(-0.20)	(0.71)	(0.39)	(0.16)
R			15.49	20.56	20.55
			(3.23)	(4.55)	(4.52)
R39-45			2.97	1.26	1.26
			(0.33)	(0.13)	(0.13)
R46-69			12.65	2.06	2.06
			(1.12)	(0.20)	(0.19)
R70-88			-8.75	-10.66	-11.32
			(-0.59)	(-0.68)	(-0.68)
R89-99			-9.56	-0.44	-0.43
			(-0.43)	(-0.01)	(-0.02)
Nuclear		0.09			.038
		(0.28)			(0.12)
R2	0.03	0.02	0.18	0.26	0.25
DW	1.59	1.59	1.98	1.94	1.95
NOBS					

Table A1 (continued)

	Textile industry				
	Model 1	Model 2	Model 3	Model 4	Model5
			CO2	CO2/FV	CO2/FV
C	1.57	1.57	2.28	0.87	0.87
	(1.05)	(1.04)	(0.99)	(0.48)	(0.48)
39-45	-2.83	-2.83	-4.71	-3.46	-3.46
	(-0.88)	(-0.88)	(-0.97)	(-0.76)	(-0.76)
46-69	1.42	1.41	1.49	2.78	2.78
	(0.66)	(0.66)	(0.50)	(1.06)	(1.05)
70-88	-0.28	-0.48	-1.22	0.17	0.02
	(-0.12)	(-0.14)	(-0.41)	(0.06)	(0.01)
89-99	2.01	1.61	0.65	2.68	2.38
	(0.72)	(0.30)	(0.15)	(0.83)	(0.41)
R			-4.33	10.24	10.24
			(-0.41)	(0.71)	(0.70)
R39-45			7.22	-6.69	-6.69
			(0.55)	(-0.40)	(-0.40)
R46-69			-4.11	-16.57	-16.57
			(-0.27)	(-0.94)	(-0.93)
R70-88			22.31	-4.77	-4.99
			(0.46)	(-0.14)	(-0.14)
R89-99			11.86	-9.70	-9.69
			(0.40)	(-0.28)	(-0.28)
Nuclear		0.04			0.03
		(0.08)			(0.06)
R2	0.02	0.02	0.04	0.04	0.04
DW	2.45	2.45	2.45	2.47	2.47
NOBS	86				

Table A1 (continued)

	Leather and rubber industry				
	Model 1	Model 2	Model 3 CO2	Model 4 CO2/FV	Model5 CO2/FV
C	0.39	0.39	-1.38	-1.57	-1.57
	(0.25)	(0.25)	(-0.57)	(-0.81)	(-0.81)
39-45	1.07	1.07	3.58	4.24	4.24
	(0.31)	(0.31)	(0.72)	(1.02)	(1.01)
46-69	3.08	3.08	4.82	4.78	4.78
	(1.37)	(1.36)	(1.33)	(1.67)	(1.66)
70-88	-0.83	-0.95	1.20	0.76	0.45
	(-0.35)	(-0.27)	(0.38)	(0.28)	(0.12)
89-99	2.96	2.73	3.44	0.10	-0.45
	(1.01)	(0.48)	(0.87)	(0.02)	(-0.07)
R			11.33	19.36	19.36
			(0.98)	(1.61)	(1.60)
R39-45			-13.77	-25.37	-25.3736
			(-0.90)	(-1.51)	(-1.50)
R46-69			-11.15	-17.01	-17.0130
			(-0.64)	(-0.98)	(-0.97)
R70-88			-60.27	-1.00	0.022
			(-0.42)	(-0.02)	(0.00)
R89-99			44.69	207.42	207.363
			(0.56)	(2.92)	(2.90)
Nuclear		0.02			0.053727
		(0.05)			(0.11)
R2	0.04	0.04	0.05	0.09	0.08
DW	2.18	2.18	2.19	2.05	2.05
NOBS	86	0.04			

Table A1 (continued)

Chemical industry					
	Model 1	Model 2	Model 3	Model 4	Model5
			CO2	CO2/FV	CO2/FV
C	1.07	1.07	-5.73	-1.81	-1.81
	(0.52)	(0.52)	(-1.87)	(-0.67)	(-0.07)
39-45	-4.27	-4.27	-2.04	-4.24	-4.24
	(-0.98)	(-0.98)	(-0.33)	(-0.76)	(-0.76)
46-69	2.26	2.26	5.61	3.80	3.80
	(0.78)	(0.78)	(1.10)	(0.94)	(0.94)
70-88	2.76	-0.52	10.81	6.57	3.14
	(0.90)	(-0.11)	(2.69)	(1.74)	(0.66)
89-99	-4.17	-10.52	-5.22	-5.64	-12.76
	(-1.10)	(-1.46)	(-0.90)	(-1.11)	(-1.60)
R			34.49	53.57	53.57
			(2.84)	(1.61)	(1.61)
R39-45			-13.02	-27.36	-27.36
			(-0.60)	(-0.63)	(-0.63)
R46-69			-19.52	-40.26	-40.26
			(-0.99)	(-1.01)	(-1.01)
R70-88			-59.67	-81.97	-90.22
			(-1.85)	(-1.53)	(-1.67)
R89-99			11.26	-13.88	-14.21
			(0.44)	(-0.32)	(-0.33)
Nuclear		0.61			0.68
		(1.03)			(1.16)
R2	0.02	0.02	0.13	0.04	0.04
DW	1.72	1.74	2.07	1.86	1.90
NOBS	86	86	86	86	86